Larry Gadbois
EPA-Richland

Dear Mr. Gadbois:

The presence of radioactive metallic specks in the Columbia River raises several difficult regulatory questions. Among these are what are the potential health effects of these particles and what protocols should be implemented for their remediation?

Potential health effects can be separated into those that are carcinogenic and those that are non-carcinogenic. The potential non-carcinogenic, or acute, effect is tissue damage in highly localized areas of the skin or respiratory tract. The short term effect of this damage would be a lesion, while the long term effect would be scar.

The carcinogenic potential of these specks primarily stems from two pathways. These are "ground shine", or external exposure, and ingestion. The maximum potential dose from ground shine has been estimated to be 0.04 mrem/year in a recreational scenario [We94]. This dose rate yields an annual cancer risk of 2.7×10^{-8}, using BEIR V risk estimates. Cooper and Woodruff published dose estimates for the ingestion pathway in 1993 [Co93]. Their estimate implies that an individual would receive a dose of 83 mrem if that individual were to ingest a speck with the highest recently-measured activity of 22 μCi. The Department of Health has estimated that the probability that an individual would ingest a speck is less than 0.31×10^{-6}. The product of this probability and the risk of the above maximum dose leads to a cancer risk per year of 0.23×10^{-10}.

The pathways of inhalation and direct contact with the skin are the means of the non-carcinogenic potential effects of specks. This is a deterministic, or nonstochastic, effect which will occur if the localized dose exceeds a threshold value and will not occur if the threshold value is not exceeded. The National Council on Radiation Protection has suggested that the contact exposure limit of 75 μCi-hrs [NCRP89] is the exposure threshold above which lesions will occur.

Cooper and Woodruff suggest that the maximum reasonable time a speck would remain directly on the skin is 48 hours, which implies that a speck with an activity of 1.6 μCi greater could exceed the 75 μCi-hr limit. Cooper and Woodruff also estimate that the localized dose equivalent to 75 μCi-hrs could be exceeded by the use of clothing containing a 1.6 μCi speck in 300 hours, and in a sleeping bag in 440 hours. These longer potential exposure times are plausible because it has been shown that specks are not easily washed out of clothing [NCRP89]. The Department of Health has conservatively estimated that the probability per year of an individual "picking up" a speck on their skin or clothing is 1.6×10^{-6} and 5.8×10^{-6} respectively.

Cooper and Woodruff also assume a 48 hour retention time for the inhalation pathway. They estimate that the dose limiting scenario for this pathway is uptake and retention of a speck in the nose. In this scenario, as in the case of direct skin exposure, specks with activities larger than 1.6 μCi will exceed the 75 uCi-hr limit. The Department of Health has estimated that the maximum probability for inhalation of a speck is 1.2×10^{-9}.

The calculations of these probabilities can be found in the Appendix, and the dose estimates are contained in the publications of Cooper and Woodruff [Co93] and the Department of Health [We94].

The maximum carcinogenic risks that have been calculated here are all several orders of magnitude below the 10^{-4} level and the maximum lesion probabilities are all approximately 10^{-6} or less. Thus the Department of Health does not believe that the human-health risks of radioactive specks in the Columbia River are sufficient to justify further surveys to locate and remove them. Nevertheless, when specks are found in the course of cleanup actions the Department recommends that they be removed. This is consistent with other environmental radiological cleanups, such as uranium mills, where "hot spots" are always remediated when they are found. Further, this recommendation does not apply to the remediation of reactor effluent pipes in the Hanford Reach of the river because it is not clear to the Department if these pipes are a significant repository of radioactive specks.

If you have any questions, please call me at 206-586-3306 or Doug Wells at 206-586-3585.

Sincerely,

John L. Erickson, Section Head

cc: Chuck Cline - Ecology
Dave Holland - Ecology
Jerry Yokel - Ecology

References

[Co93] A.T. Cooper and R.K. Woodruff, "Investigation of Exposure Rates and Radionuclide and Trace Metal Distributions Along the Hanford Reach of the Columbia River", Pacific Northwest Laboratories document number PNL-8789, Richland, WA (1993).

[We94] D.P. Wells, "Radioactivity in Columbia River Sediments and their Health Effects", Washington Department of Health, Olympia, WA (1994).

[EPA91] T. Fields and B. Diamond, "Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors", Washington, DC (1989).

[HSBRAM] "Hanford Site Baseline Risk Assessment Methodology", US Department of Energy publication number DOE/RL/-91-45, Richland, WA (1992).

[NCRP89] "Limit for Exposure to Hot Particles on the Skin", NCRP report number 106, National Council on Radiation Protection and Measurements, Washington, DC (1989).

[Sc93] R.G. Schreckhise *et al.*, "Recommended Environmental Dose Calculations Methods and Hanford Specific Parameters", Pacific Northwest Laboratories document number PNL-3777, Richland, WA (1993).

[Sh92] B. Shleien, Editor, "The Health Physics and Radiological Health Handbook", Scinta Press Inc., Silver Spring, MD (1992).

[Su80] M.J. Sula, "Radiological Survey of Exposed Shorelines and Islands of the Columbia River between Vernita and the Snake River Confluence", Pacific Northwest Laboratories document number PNL-3127, Richland, WA (1980).

Appendix - Probability Estimates

A complete risk assessment of radioactive specks in sediments includes both an estimate of the carcinogenic and non-carcinogenic effects if an individual is exposed and the probability of exposure. The Department of Health calculates this probability for each pathway by dividing the volume of sediments that the "maximally exposed individual" is exposed to each year by the minimum sediment volume that is likely to contain one speck. The latter quantity is the inverse of the maximum speck density as measured by Sula [Su80] on D-Island.

Sula found that the maximum number of specks per unit area was 5.6×10^{-3} m^{-2}. Since all of these specks were found to be in the top 15 cm, this yields a volume density of 3.7×10^{-2} m^{-3}. The inverse of this yields the minimum single-speck sediment volume of 2.7×10^{7} cm^3.

To estimate the volume of sediment ingested per year by the maximally exposed individual the Department of Health assumed a consumption rate of 200 mg/day [HSBRAM] for 63 days per year. This is a 500 hours-per-year recreational scenario[Sc93], which is approximately ten times more conservative than the Hanford Site Baseline Risk Assessment Methodology. This yields an annual consumption rate of 12.6 grams per year, or assuming a sediment density of 1.5 g/cm^3, 8.4 cm^3 per year. Thus the annual probability of consumption is 8.4 cm^3 divided by 2.7×10^{7} cm^3, or 0.31×10^{-6}.

The mass of sediment inhaled per year is given by the product of three factors: the breathing rate (approximately 1 m^3/hr), the number of hours spent recreating on the river (500 hours) and the mass-loading of suspended sediment in the air (0.0001 g/m^3)[Sc93]. The latter factor is twice as conservative as EPA's guidance [EPA91]. This yields an annual inhalation of 0.05 g, or assuming a sediment density of 1.5 g/cm^3, an annual inhalation of 0.033 cm^3 of sediment. Thus the annual probability of inhalation is given by 0.033 cm^3 divided by 2.7×10^{7} cm^3, or 1.2×10^{-9}.

The mass of sediment that annually adheres directly to the maximally exposed individual's skin is given by the product of three factors: the adherence rate (0.0002 g/cm^2 per day) [HSBRAM], the area of uncovered skin (5.000 cm^2) [HSBRAM] and the number of days per year (63 days). This yields an annual mass of 63 g, or 42 cm^3. Thus the probability of a speck adhering to the skin is 42 cm^3 divided by 2.7x107 cm^3, which yields an annual probability of 1.6×10^{-6}.

To calculate the probability of a speck adhering to clothing, the Department follows the calculation for adherence to skin, with the area of 5,000 cm^2 replaced by the area of a "reference man" [Sh92] (18,000 cm^2). This yields an annual probability of 5.8×10^{-6}.

These estimates utilized many conservative assumptions; however, it is important to keep several potential modifications in mind. Most of the specks are found in rocky areas where sediments are only found in the spaces between the rocks. Thus the above estimate of the density of specks in sediments available for uptake may be too low. Inclusion of this effect would reduce the minimum single-speck volume and raise the above probabilities. However, in rocky locations most of the surface area that is available for contact, ingestion or resuspension is taken by the rocks and not the sediments. Inclusion of this effect would reduce the above probabilities. Further, the density of specks is approximately three times that of a sediment "grain". This causes specks to sink below the surface, further reducing the probability of contact. The net result of these effects tends to cancel. Thus the Department of Health is confident that the probabilities calculated here are conservative estimates.